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# IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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| **In the application of** | : | Alan Robinson |
| **Serial No.** | : | 09/739,529 |
| **Filed** | : | December 15, 2000 |
| **For** | : | Optical Fiber Amplifier |
| **Examiner** | : | George Y Wang |
| **Art Unit** | : | 2871 |

*I hereby certify that this correspondence is being transmitted to the above – identified examiner at the United States Patent and Trademark Office (703) 872-9319 on July 23, 2003.*
**Name of person signing** Jennifer J. Ramirez
**Signature**

**RESPONSE TO OFFICE ACTION MAILED MAY 23, 2003**

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TECHNOLOGY CENTER 2800

Honorable Director of Patents and Trademarks
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir,

In response to the Office Action mailed May 23, 2003, the applicants have the following remarks below. No amendments are being filed as none are believed appropriate.

In response to paragraph 1 of the Detailed Action, the Examiner is correct to presume that the subject matter of the various claims was commonly owned at the relevant time.

In paragraph 2 of the Detailed Action, the Examiner rejects claims 1-9 of the present application under 35 USC §103(a) as being unpatentable over a combination of Brown (US 6,317,549), Imoto (US 5,742,722) and Hodges et al (US 4,838,643).

Non-obviousness is therefore the <u>sole issue</u> that governs allowability of the present application. Applicants will show in this Response that:

1) the design requirements of gain fibers and transmission fibers are extremely different;
2) conventional gain fibers have employed smaller mode field diameters than conventional transmission fibers;
3) the prior art cited by the Examiner merely serves to reinforce the above contention; and
4) therefore, it was non-obvious to provide the claimed optical amplifier having, in particular, a mode field diameter of greater than 10 μm (with the refractive index between core and cladding selected such that the cut-off wavelength at which the fiber becomes single-mode lies in the range 1000-1550 nm).

<u>Design Requirements:</u>

Neither Brown, nor Hodges relate to <u>gain fibers</u>. Rather, they relate to <u>transmission fibers</u>. Imoto, however, relates to gain fibers. In combing these references, the Examiner has asserted that gain fibers and transmission fibers have "practically identical" design requirements. Applicants respectfully disagree.

The reason design requirements are different between gain fibers and transmission fibers is in part due to the <u>differing length requirements</u> of each type of fiber. Typically, transmission fiber span lengths (the distance between adjacent amplifier or regenerator locations) are greater than 40km, whereas the length of fiber utilized in each amplifier is in the region of tens of meters giving rise to very different design requirements.

Another reason why the design requirements are different between gain fibers and transmission fibers is due to differing functions they perform. The fundamental purpose of transmission fibers is to transport optical signals from one location to another, with the minimum distortion and attenuation. This contrasts totally with the purpose of gain fibers which is to provide gain to optical signals, while introducing the minimum amount of noise. It must be highlighted that 'noise' and 'distortion' are different physical effects and are in no way equivalent.

The Examiner argues "low noise and efficient light energy conversion is functionally the same as interference reduction and low optical loss". Again, Applicants firmly believe that this is incorrect for the following reasons:

'Low noise' is a requirement that is only applicable to gain fibers – noise is not introduced in a transmission fiber, and therefore 'low noise' is a meaningless parameter of a transmission fiber.

'Efficient light energy conversion' is again only applicable to gain fibers and refers to the conversion of energy from the pump wavelength to the signal wavelength. In transmission fiber there is no requirement for this conversion of energy since there is no pump energy inserted into the fiber, there are no dopants present to allow this conversion of energy and there is no desire to provide gain to the signal.

'Interference reduction' refers to the use of fiber with low chromatic dispersion. Chromatic dispersion and optical loss in a system are both functions of fiber length, and are insignificant over the lengths of gain fiber utilised in optical amplifiers. They are therefore only applicable to transmission fibers.

Thus, the four parameters cited by the Examiner (low noise, efficient light energy conversion, interference reduction and low optical loss) have been shown to be

different, with each parameter only applicable to one of the fiber types, and not to the other fiber type.

It is therefore submitted that the design requirements of gain fiber and transmission fiber are extremely different.

<u>Conventional Gain Fiber Design:</u>

Established erbium fiber (i.e. gain fiber) designs use a smaller diameter core than transmission fiber, with high refractive index difference between core and cladding thereby having a smaller mode field diameter (MFD). There are a number of factors driving this, well known to designers of erbium fiber amplifiers.

1) The most efficient utilization of pump energy is achieved when the mode field diameters of both pump and signal are small. This is particularly important when input powers are small, but advantages of small MFD remain even at very high power levels.

2) The best overlap between the pump energy and the signal to be amplified is achieved when the fiber cut-off wavelength is substantially less than that of the pump wavelength. For erbium doped fiber amplifiers, the wavelengths of pump sources are typically close to either 980 nm or 1480 nm.

3) Large mode field diameters are associated with increased bend loss (cf. Hodges). This trend is greatly exacerbated in fibers with short cut-off wavelengths.

4) Best values for noise figure are achieved with 980 nm pumping, which requires short cut-off wavelengths.

5) Acceptable bend performance with 1480 nm pumping requires either a cut-off which is comparable with the pump wavelength, or a high core-cladding refractive index difference and a small mode field diameter. Designs with cut-off wavelength close to the pump wavelength have reduced pump intensity at the core boundary. In high mode field diameter designs, the pump efficiency is reduced and the noise figure degraded compared with conventional designs.

6) There is a need to minimize the volume occupied by amplifies, and good bend performance allows the fiber to be coiled into a smaller space. This is another driver for small MFD fiber.

Prior Art References:

Returning to briefly discuss the cited prior art, Applicants note that none of the references are cited as anticipating the claimed invention. The sole issue is non-obviousness. The cited references fall into two camps: transmission fiber related references (Brown and Hodges) and gain fiber related reference (Imoto, Wiedman).

Hodges relates to bend resistant transmission fibers in particular. The specific sentence cited by the Examiner (column 1, lines 34-36) simply reinforces what Applicants explicitly acknowledge in the present application (page 2, line 5) that conventional transmission fibers typically have mode field diameters up to 11 μm for light at 1550 nm. Brown also discloses a transmission fiber within conventional design parameters.

In contrast, Imoto discloses gain fiber having mode field diameter of 8.8 µm (column 6, lines 12 to 19). Furthermore, Wiedman (US 5 295 211), discloses gain fiber with a mode field diameter of 4 to 6 µm at 1550 nm. In fact, the teaching of Wiedman shows that considerable effort has been applied to the problem of splicing between transmission fibers (with large MFD) and gain fibers (with small MFD). This again merely serves to reinforce Applicants' contention that conventional gain fiber designs use a smaller diameter core (and therefore MFD) than transmission fiber.

Non-Obviousness:

Applicants have shown that the design requirements of transmission fiber and gain fiber are extremely different. Applicants have also shown why conventional gain fiber design has used a smaller MFD and that the prior art cited by the Examiner serves to reinforce this contention. As a result, it is submitted that one of ordinary skill in the art of gain fiber design, would not have been motivated to design gain fiber having larger MFD as claimed. This goes wholly against conventional design wisdom.

Applicants have boldly thrown away conventional design wisdom and have instead designed gain fiber having larger MFD than previously contemplated.

This is advantageous in systems carrying multiple wavelength multiplexed signals, at relatively high optical powers. In terms of conventional measures of amplifier performance, such as noise figure and conversion efficiency, a large MFD amplifier will still offer poorer performance. However, Applicants have realized that performance in terms of low frequency distortion and cross-gain modulation is enhanced if large MFD fiber is used for the high power output stages of the amplifier.

Applicants' contention is not that it is unusually difficult to make fibers of the design claimed. Rather, it would not have been apparent, to one of ordinary skill in the art, that such a fiber design would have been worth making. Thus, the invention, as claimed, is submitted to be allowable.

Applicants submit that the response raises no new issues and request that the Examiner favorably reconsider the present application.

July 23, 2003

Respectfully submitted,

William M. Lee

William M. Lee, Jr.
Registration No. 26,935
Barnes & Thornburg
P.O. Box 2786
Chicago, Illinois 60690-2786
(312) 214-4800
(312) 759-5646 (fax)

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# Barnes & Thornburg

**Attorneys at Law**
One North Wacker Drive, Suite 4400
Chicago, Illinois 60606-2809
Telephone: (312) 357-1313
Fax: (312) 759-5646

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# BARNES & THORNBURG

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Chicago, IL 60690-2786

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EXAMINER: George Y. Wang

GROUP ART UNIT: 2871

ATTN **Examiner**

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**Attached:** Response To Office Action Of May 23, 2003

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If you do not receive all pages, please contact William M. Lee, Jr. at (312) 214-4800 or his assistant, Jennifer Ramirez at (312) 214-4829.

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I hereby certify that this paper for Serial No. 09/739,529 facsimile transmitted to the Patent and Trademark Office, Fax Number (703) 872-9319 on the date shown below.

Jennifer J. Ramirez
Name of Person Signing

Signature

July 23, 2003